



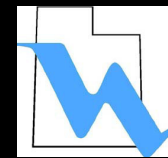
Membrane Bioreactors 101

Marie-Laure Pellegrin, Ph.D.
marie-laure.pellegrin@hdrinc.com

National Operators Trainers Conference
June 11, 2008

HDR

ONE COMPANY | *Many Solutions™*





Proposed Presentation Outline

- Membrane Filtration Basics
- Membrane Equipment Description and Functions





HDR

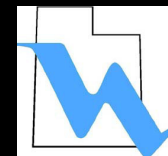
ONE COMPANY | *Many Solutions™*

WEFPRESS
For the Water Quality Professional

**Water Environment
Federation®**
*Preserving & Enhancing
the Global Water Environment*

Membrane Systems for Wastewater Treatment

WATER ENVIRONMENT FEDERATION (WEF)

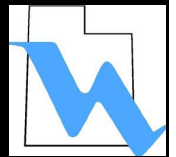




Membrane Filtration Basics

HDR

ONE COMPANY | *Many Solutions™*





What is a Membrane?

- Separation device like a clarifier to separate suspended solids from the water
- Physical barrier: suspended solids bigger than pore size remain in the process tank

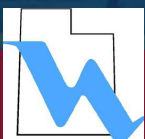
Mixed Liquor

MLSS 5,000 –
14,500 mg/L

Permeate

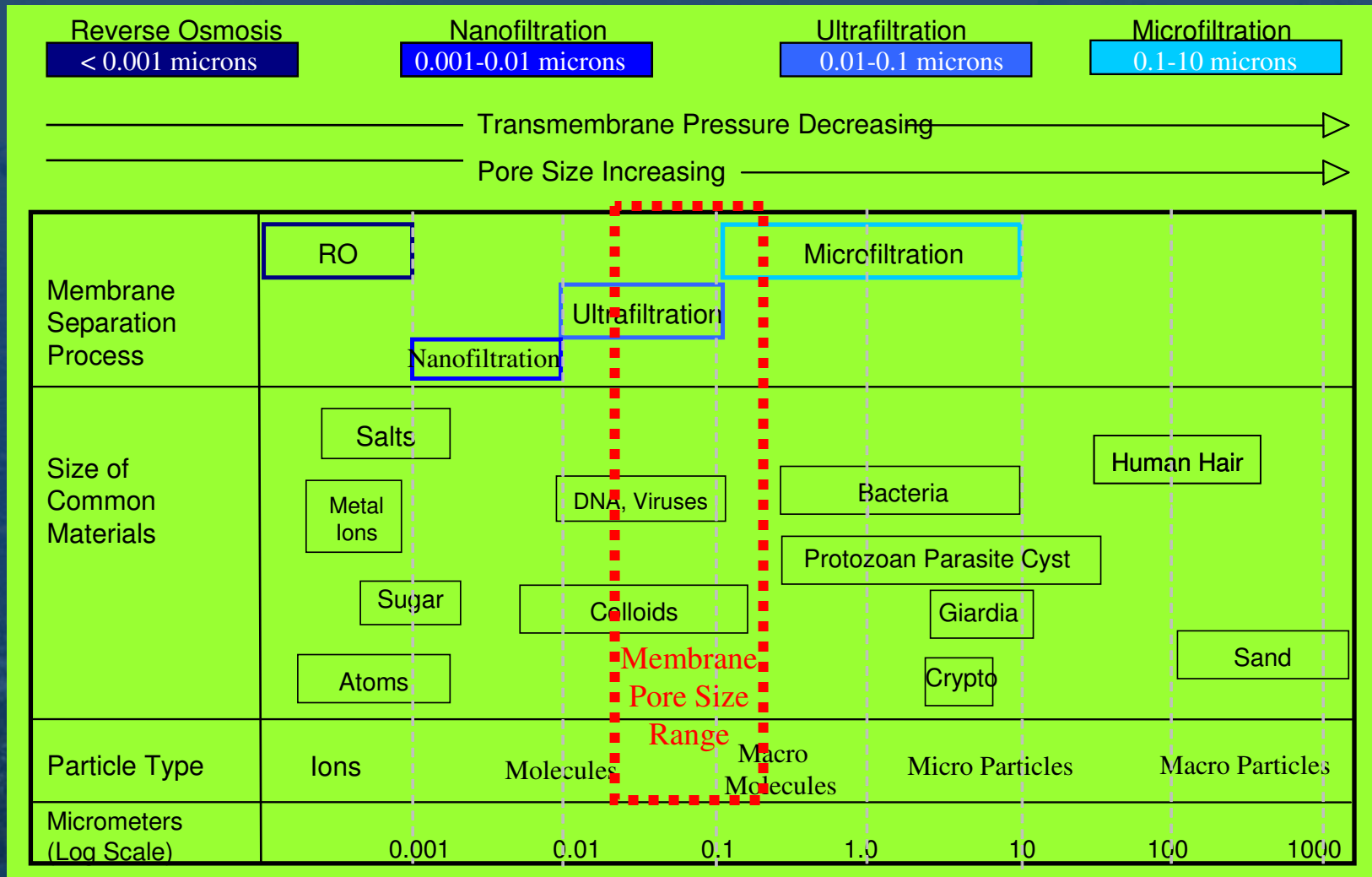
TSS < 1 mg/l
Turbidity < 0.2 NTU

Flow

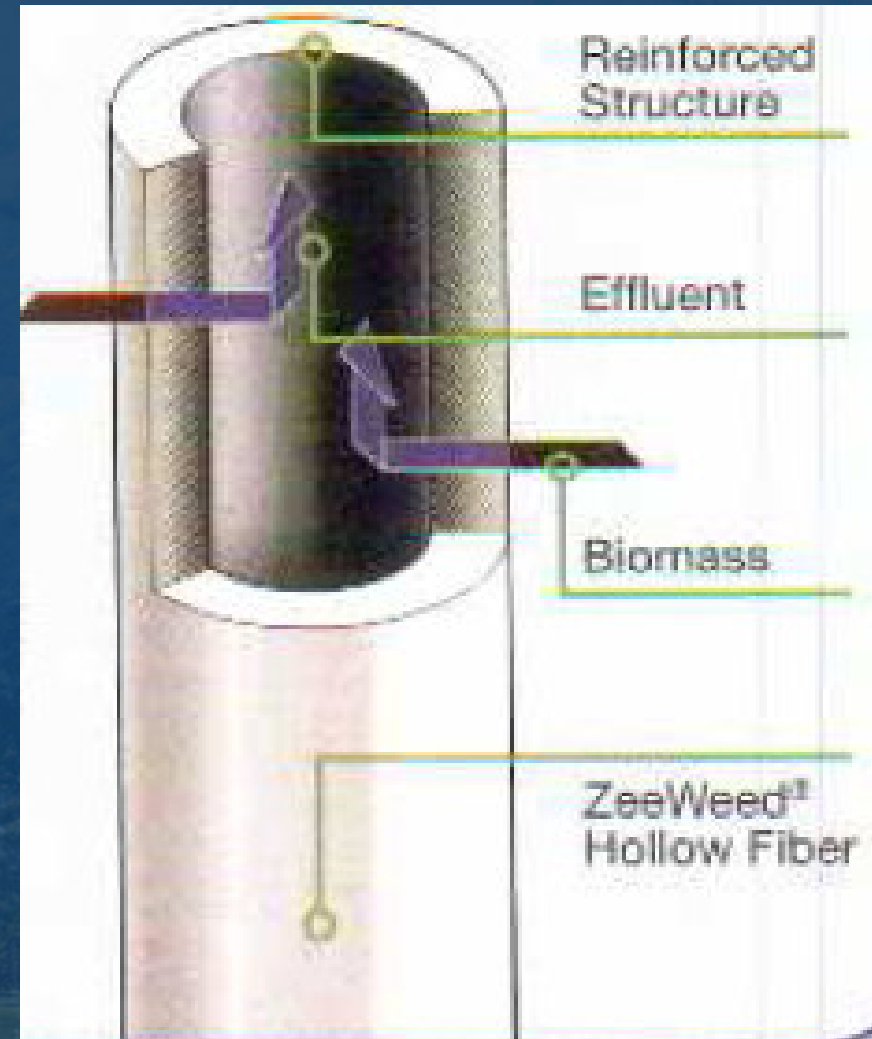
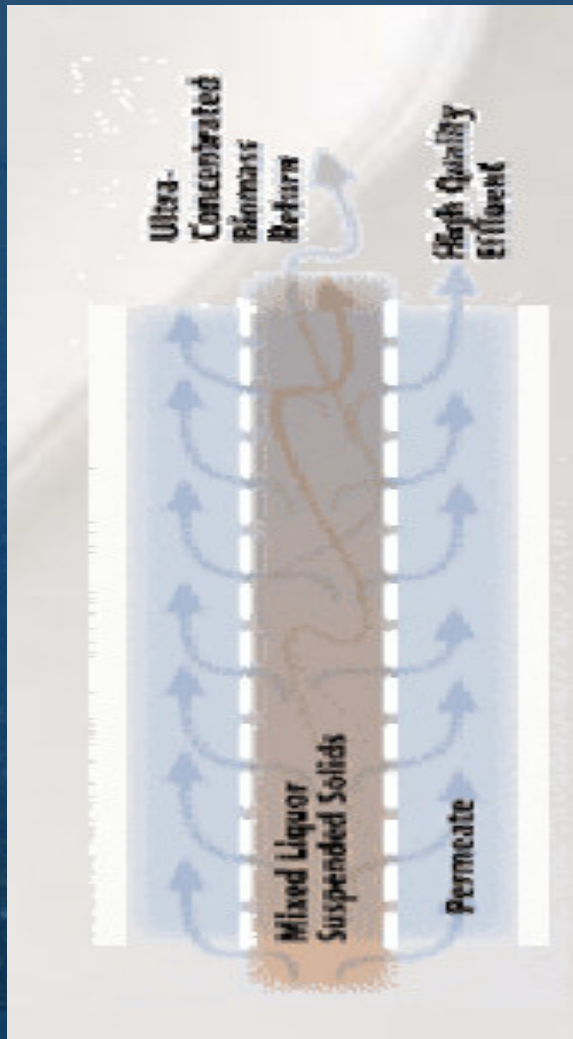




Membrane Filtration Spectrum



Typical Types of Membranes: Hollow Fibers

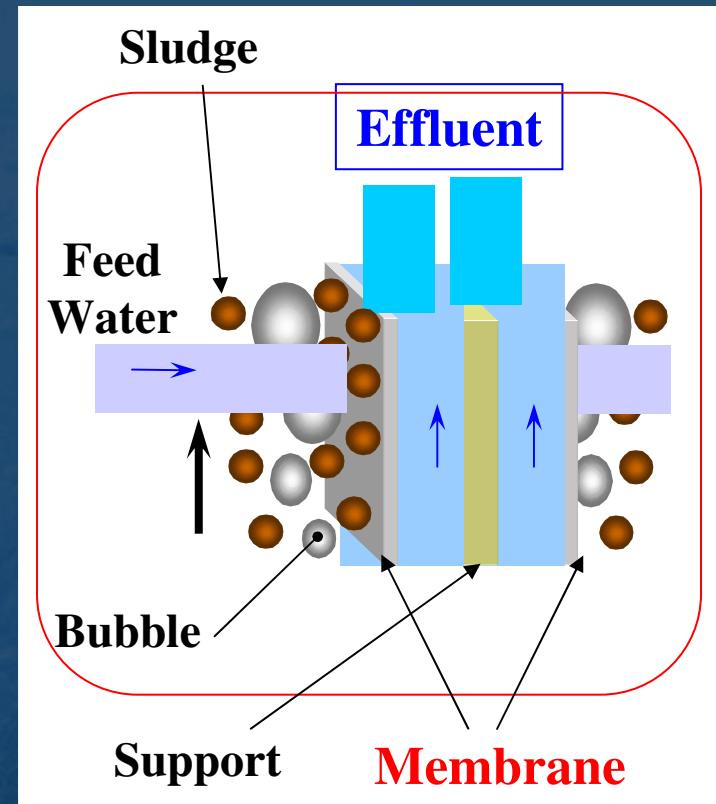
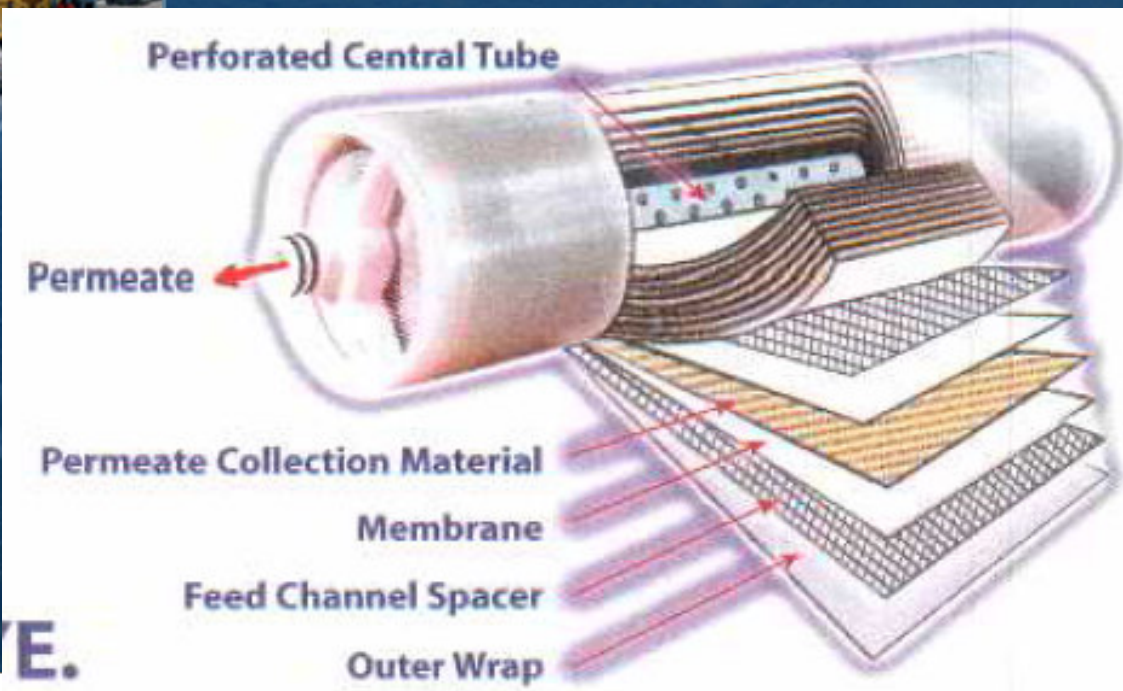
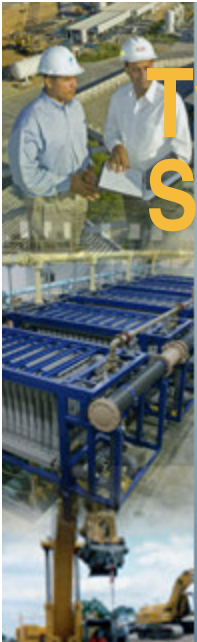


Inside/out (pressurized)

Outside/In (vacuum)



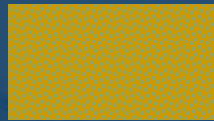
Typical Types of Membranes: Flat Plate and Spiral Wound



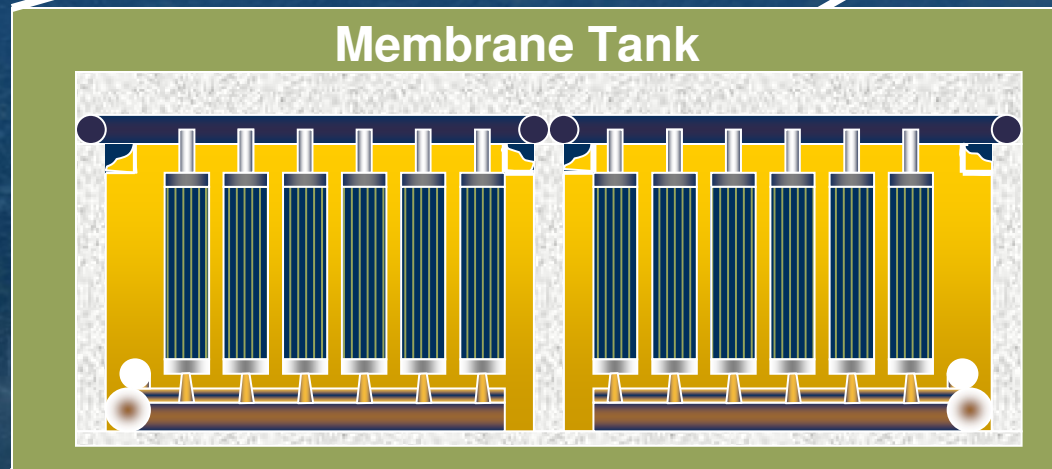


MBR: Membrane BioReactor

Fine screening

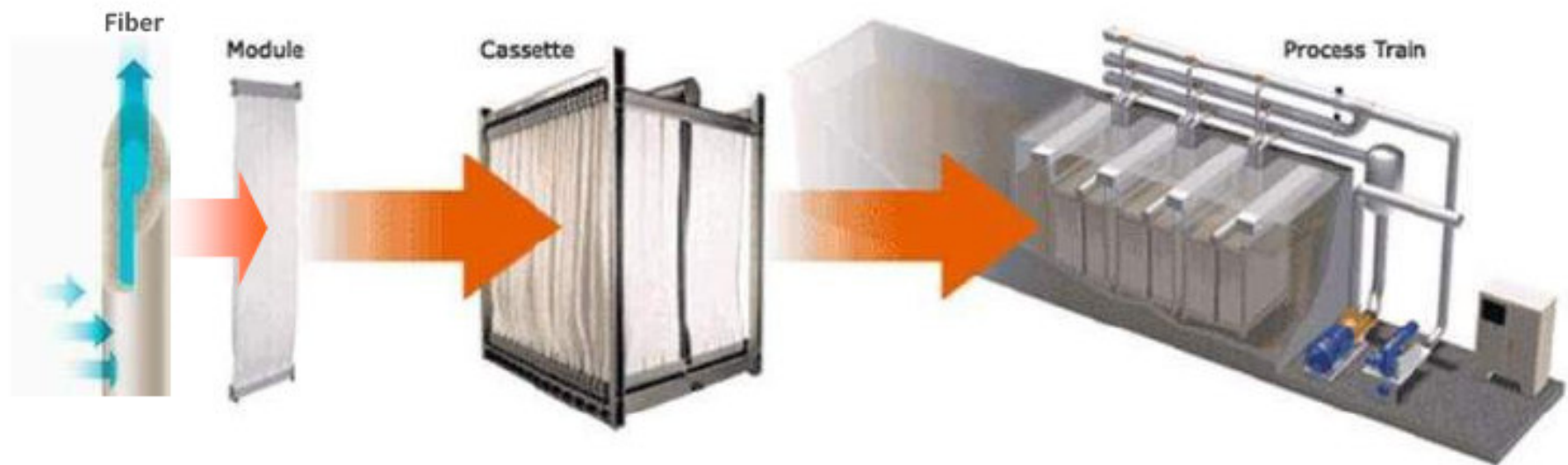


Typical
MBR Layout





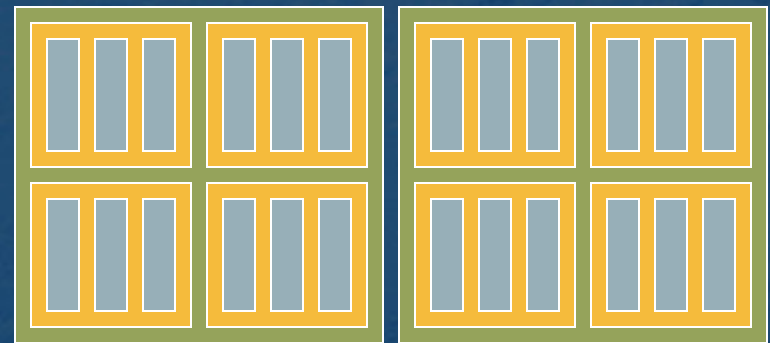
Module/Cassette/Membrane Tank





Membrane Surface Area (A)

- Total surface area across which mixed liquor is filtered
- Example:
 - 2 membrane tanks (MT)
 - 4 cassettes per tank (C)
 - 3 modules per cassette (M)
 - Each module has 200 ft² of membrane surface area (S)



$$A = MT * C * M * S = 2 * 4 * 3 * 200 = 4,800 \text{ ft}^2$$

available for filtration





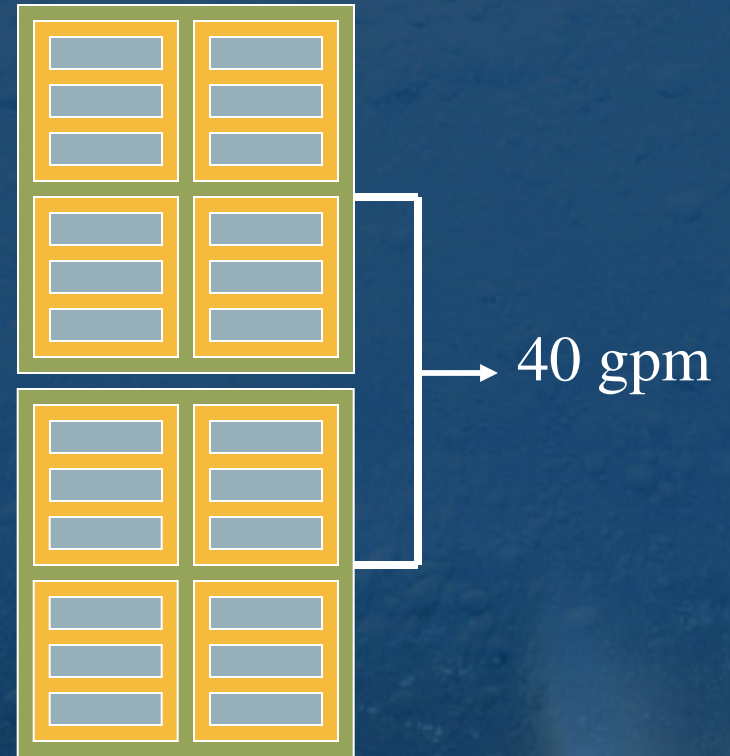
Instantaneous Flux J_T

- Instantaneous flow across membranes (as measured by flow meter) per membrane surface area (gfd = gpd/ft²)

- Example:
 - Instantaneous flow: 40 gpm
 - A: 4,800 ft²

$$J_T = \text{Flow} / A =$$

$$[40 \text{ (gpm)} * 1440 \text{ (min/d)}] / 4,800 \text{ (ft}^2\text{)} = 12 \text{ gfd}$$





Instantaneous Flux Normalized with Temperature

- Instantaneous flux J_T corrected for water viscosity based on temperature. Normalized for 68°F (20°C)
- Example:
 - $J_{11} = 12$ gfd at 11°C
 - Viscosity at 20°C = $\mu_{20} = 1$ centipoise
 - Viscosity at 11°C = $\mu_{11} = 1.24$ centipoise

$$J_{20} = J_{11} * \mu_{11}/\mu_{20} = 14.9 \text{ gfd}$$

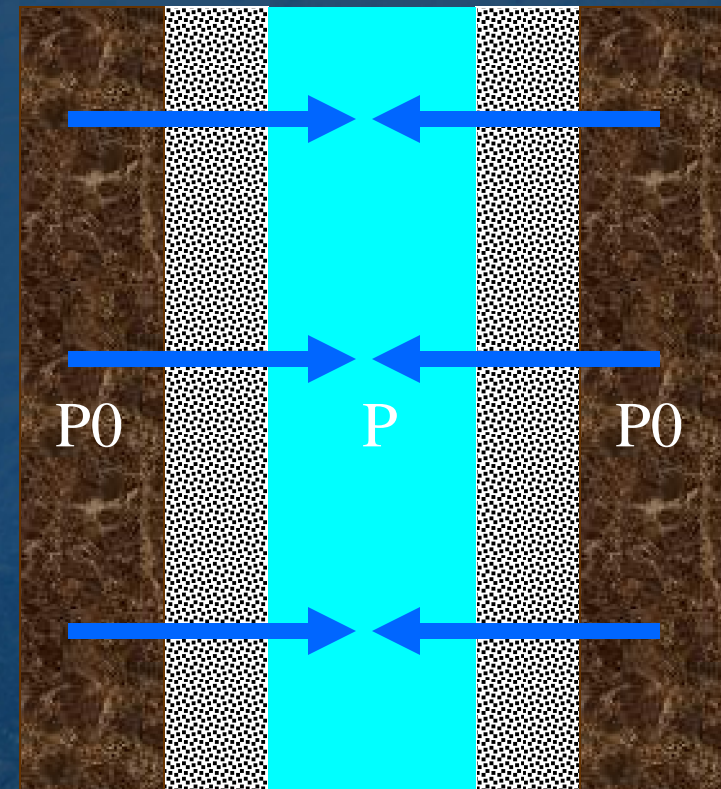




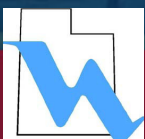
TransMembrane Pressure (TMP)

- Pressure across the membrane surface or headloss through the filter (psi)

TMP = feed pressure (P_0)
– permeate pressure (P)



Membrane Wall





Permeability

- Flux divided by TMP (gfd/psi)
- For example:
 - Flux $J_{20} = 14.9$ gfd
 - TMP = 3 psi

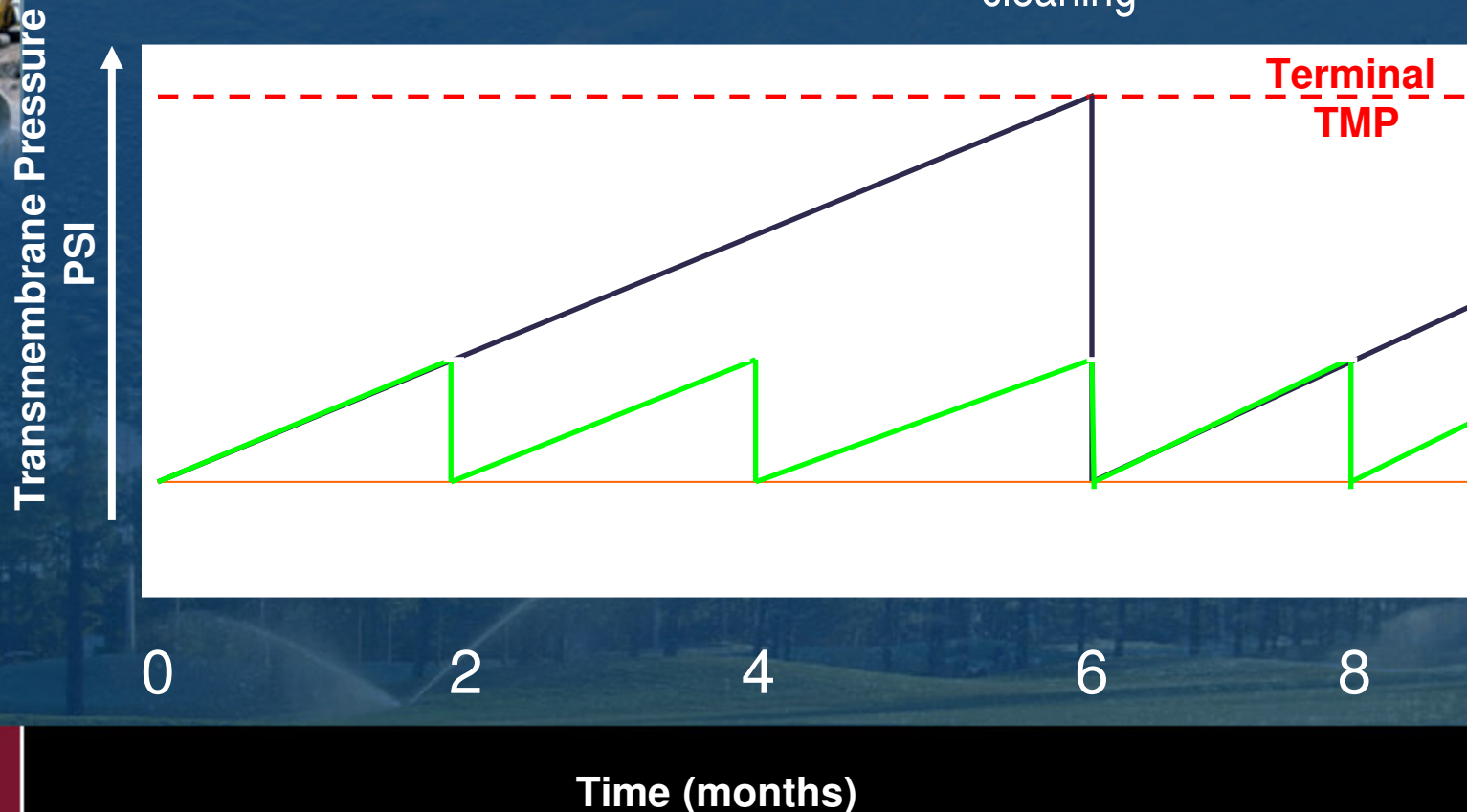
$$\text{Permeability} = J_{20} / \text{TMP} = 14.9 / 3 = 5 \text{ gfd/psi}$$





Fouling

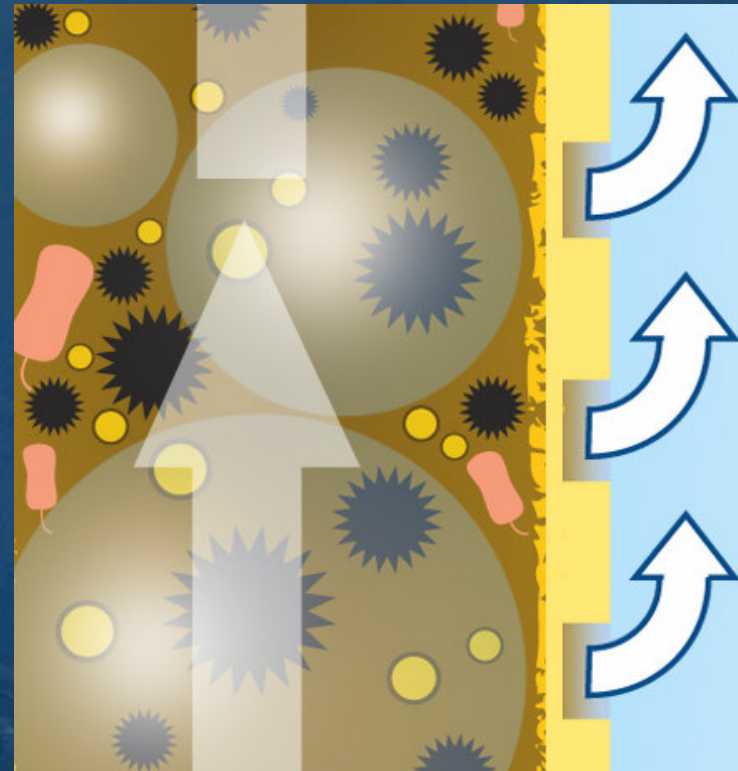
- Types:
 - Particulate/colloidal: pore blocking, cake layer formation
 - Organic
 - Biofouling: attachment of microorganisms, biofilm formation
- Effects:
 - TMP increase (or flux reduction) caused by adsorption, deposition/build up of contaminants on/in the membrane
 - Fouling controlled by membrane cleaning





BioFilm and Biohydraulics

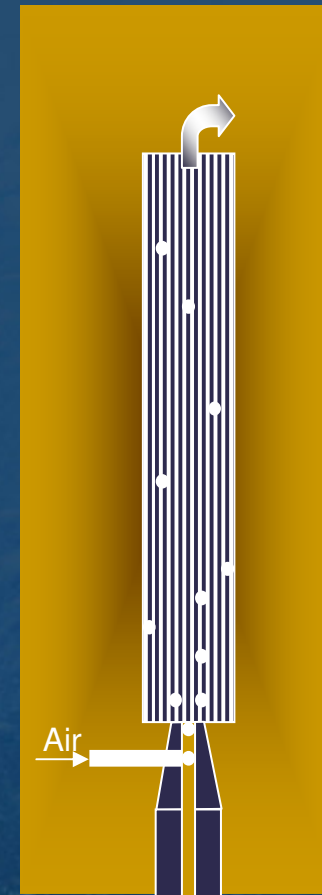
- **BioFilm:** thin layer of sludge on the membrane surface
- **Biohydraulics:** interrelationship between the biological process and the membrane hydraulic characteristics (term developed by Enviroquip)



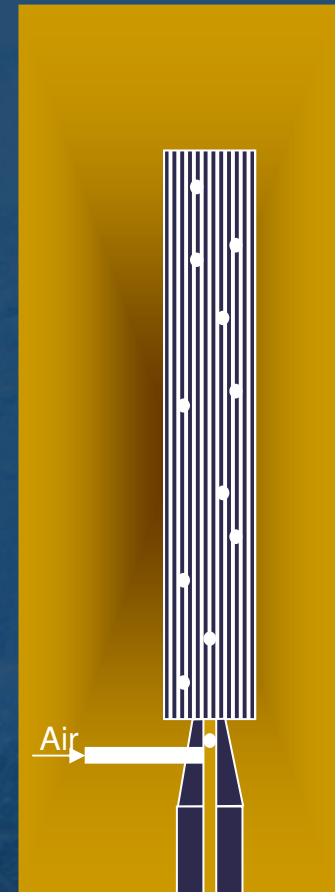


Relaxation

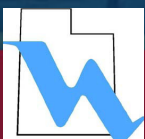
- Completely Automated
- Every 12 minutes to reduce solids buildup on membrane surface
- 60 s duration
- Filtrate pumps are stopped
- Relieves solids tension on membrane surface so they are scoured away



Filtration



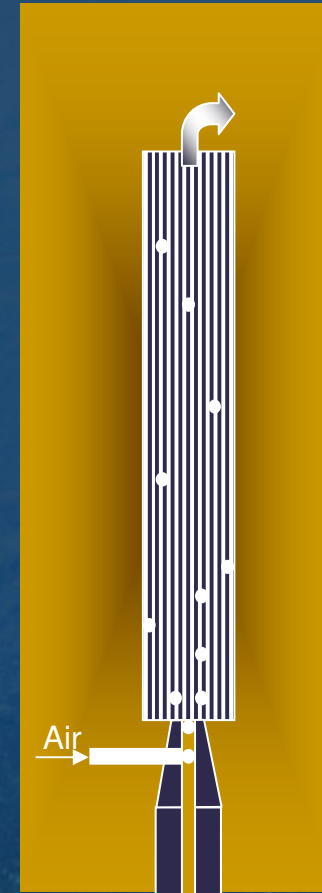
Relaxation



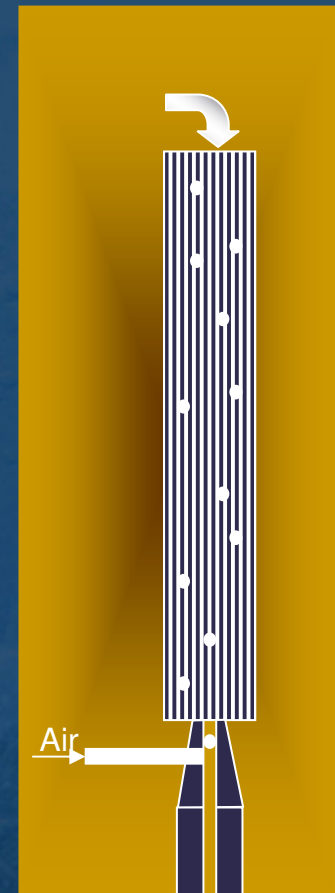


Backwash

- Completely Automated
- Using periodically to reduce solids buildup on membrane surface
- Reverse flow utilizing filtrate pumps



Filtration



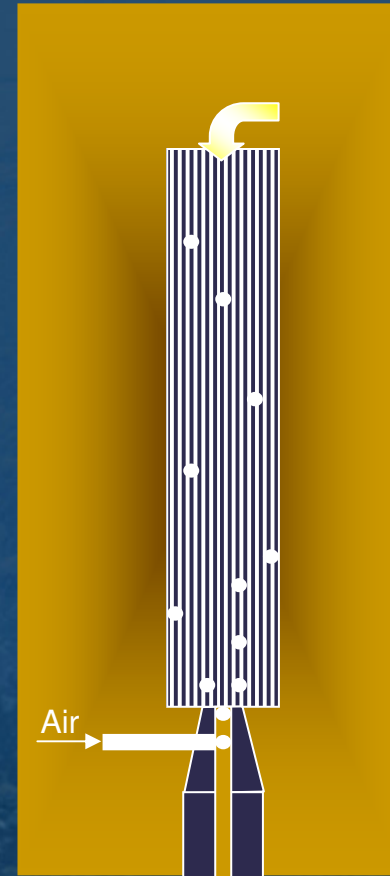
Backwash



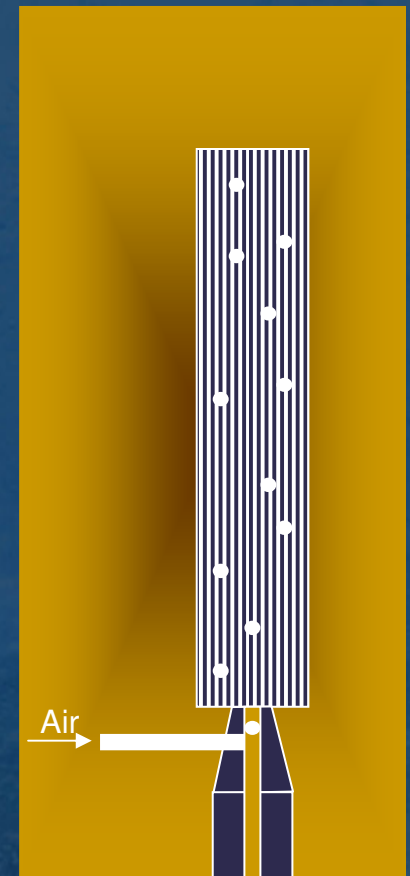


Maintenance Clean

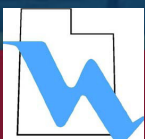
- Completely Automated
- Every 1-2 week(s)
- Air stays ON
- Mixed liquor pump is stopped
- Mixed liquor remains in tank
- Protocol:
 - Backwash with chlorine (200 mg/L)
 - Relaxation for 15 minutes
- 30-40 minutes duration
 - Inhibits biological surface fouling



Backwash with chlorine



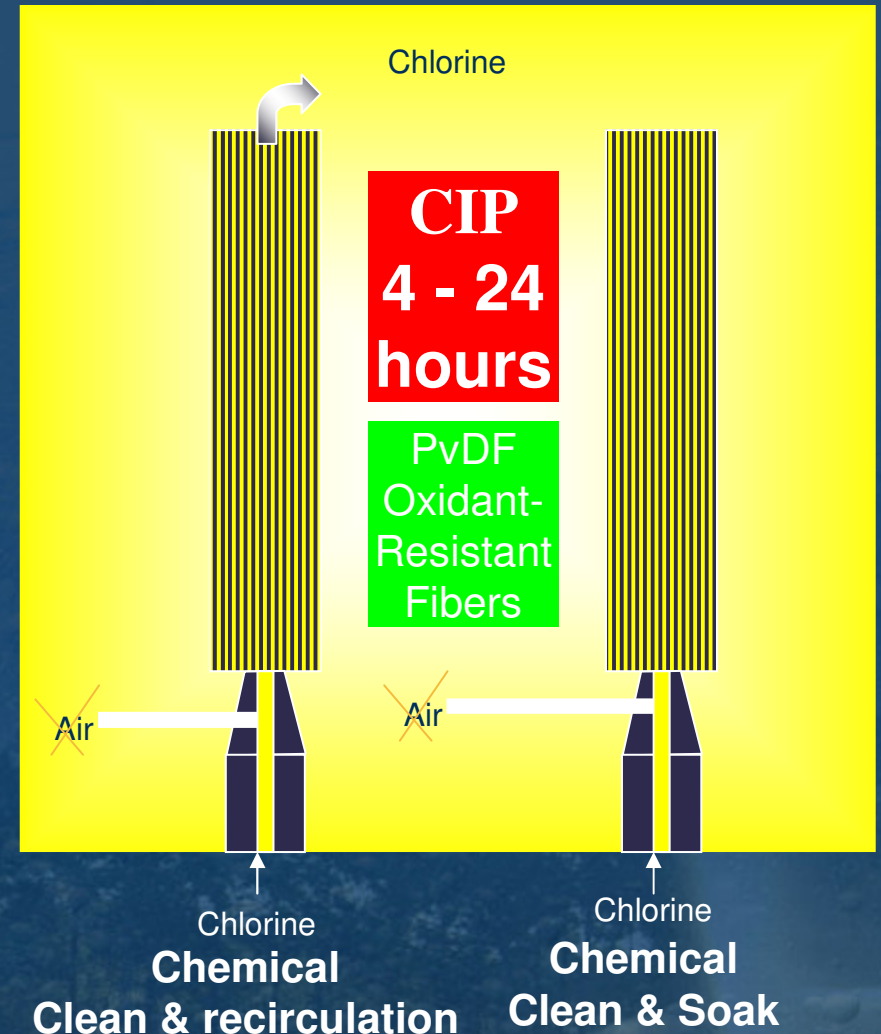
Relaxation





CIP or Clean In Place

- Automated – no membrane removal
- Every 3 months or if TMP > 35 kPa at average design flux or permeability < 80 LMH/bar
- 4-24 hours per membrane cell
- Mixed liquor is sent back to biological tanks
- Utilizes chlorine at approximately 1,500 mg/L
- Occasional acid cleans for inorganic fouling
- Used CIP solution is wasted or recycled within the plant (job specific)





Other terms

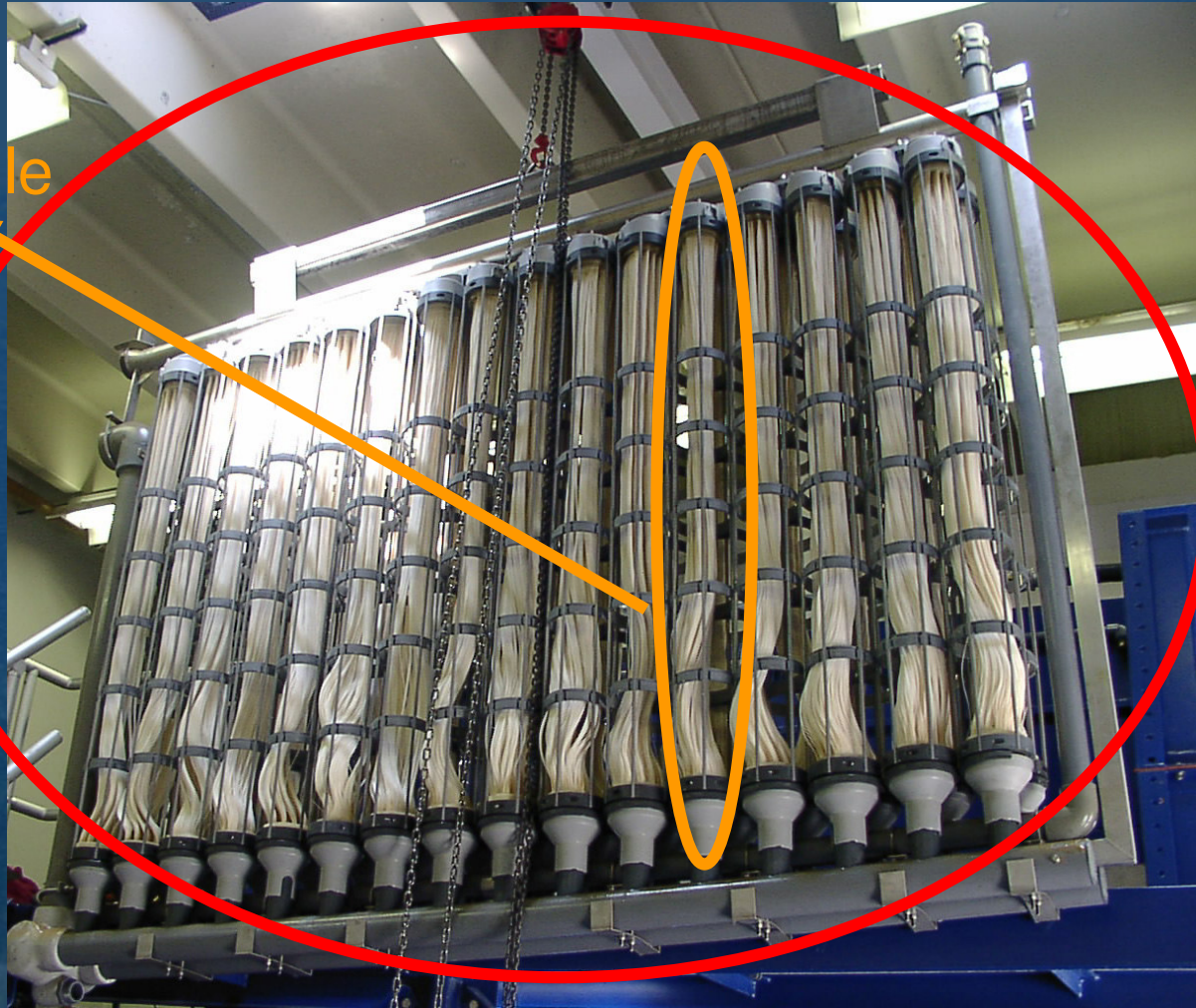
- **Filtrate (or permeate)**: Treated water or effluent from the membranes.
- **Integrity Test**: Test allowing leak identification on the permeate side (piping and membranes)
- **Time To Filter (TTF)**: amount of time required to filter a fixed volume of sludge through a filter paper



What does it look like (rack scale)?



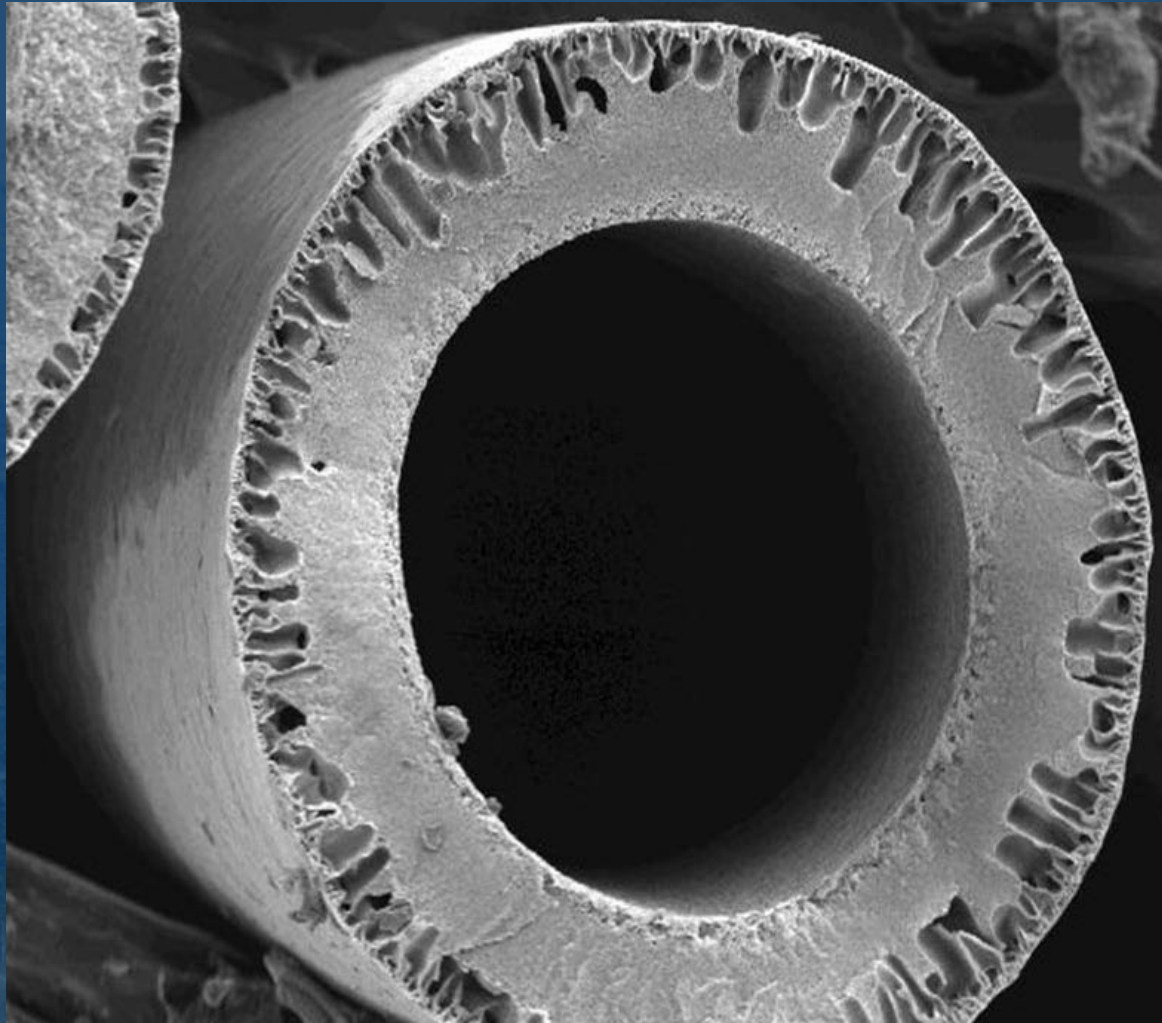
1 module



1 rack

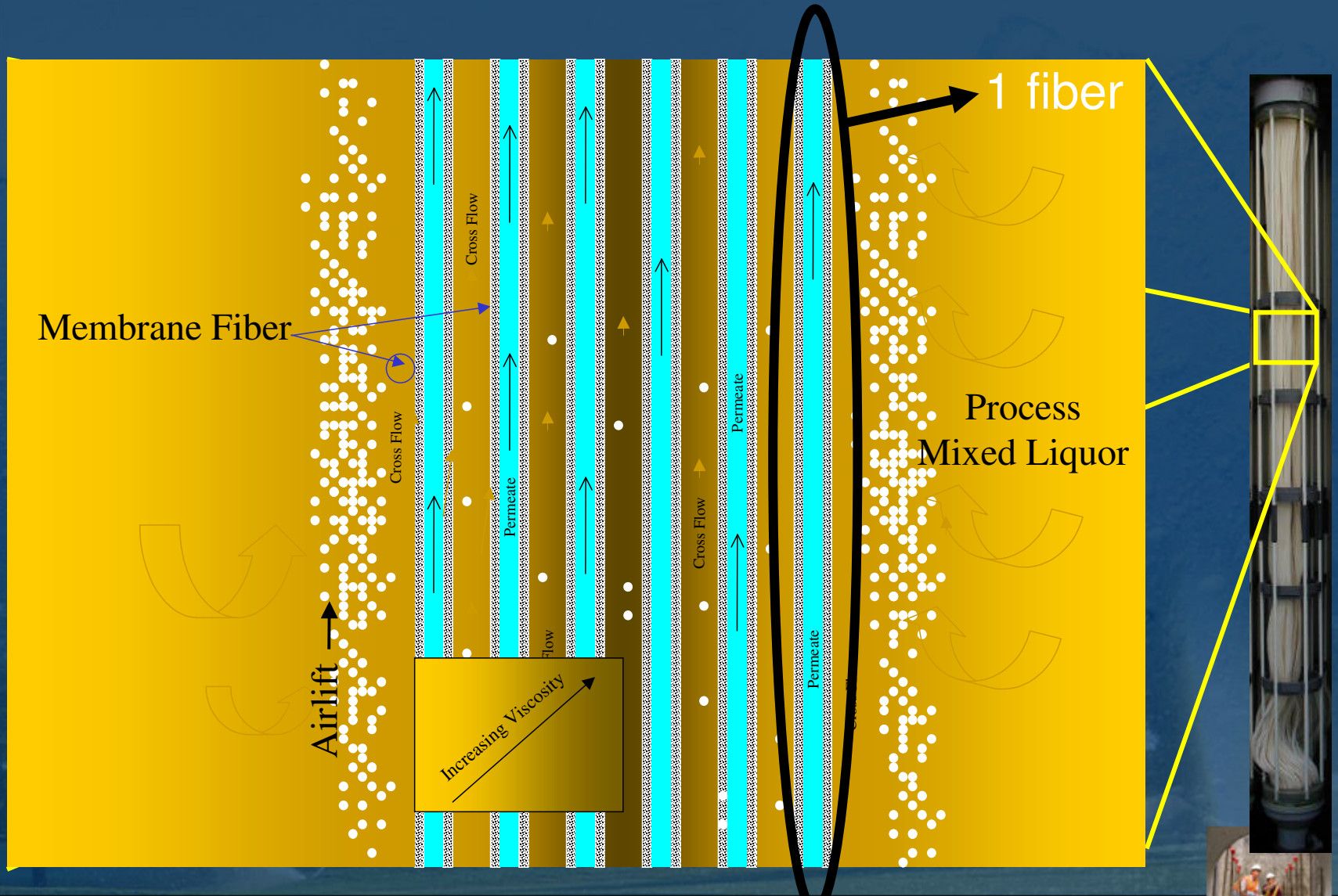


What does it look like (fiber scale) ?

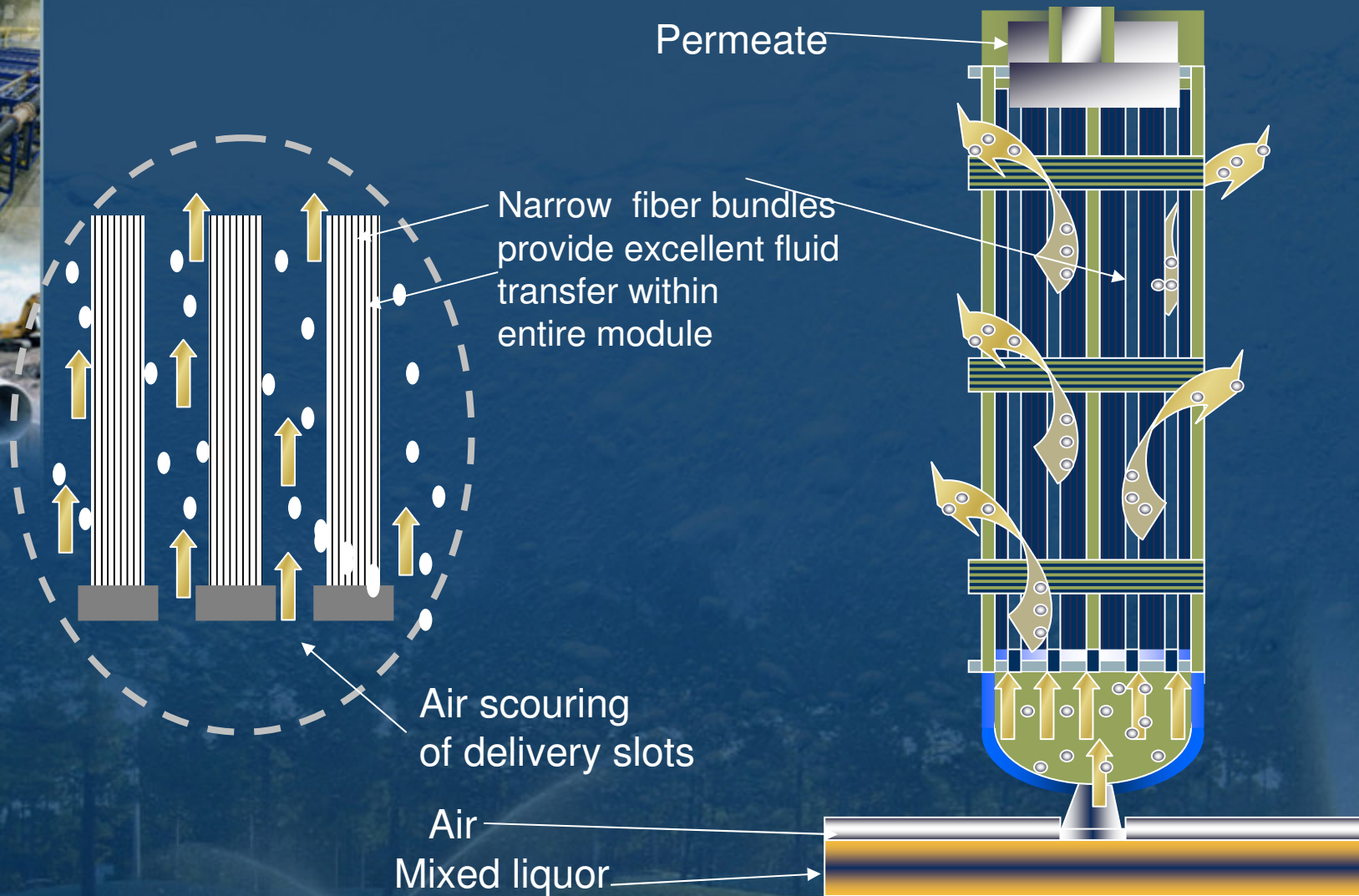




How does it work at the fiber scale ?



How does it work at the module scale ?

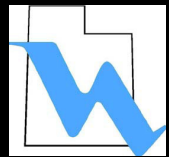




Membrane Equipment Description and Functions

HDR

ONE COMPANY | *Many Solutions™*



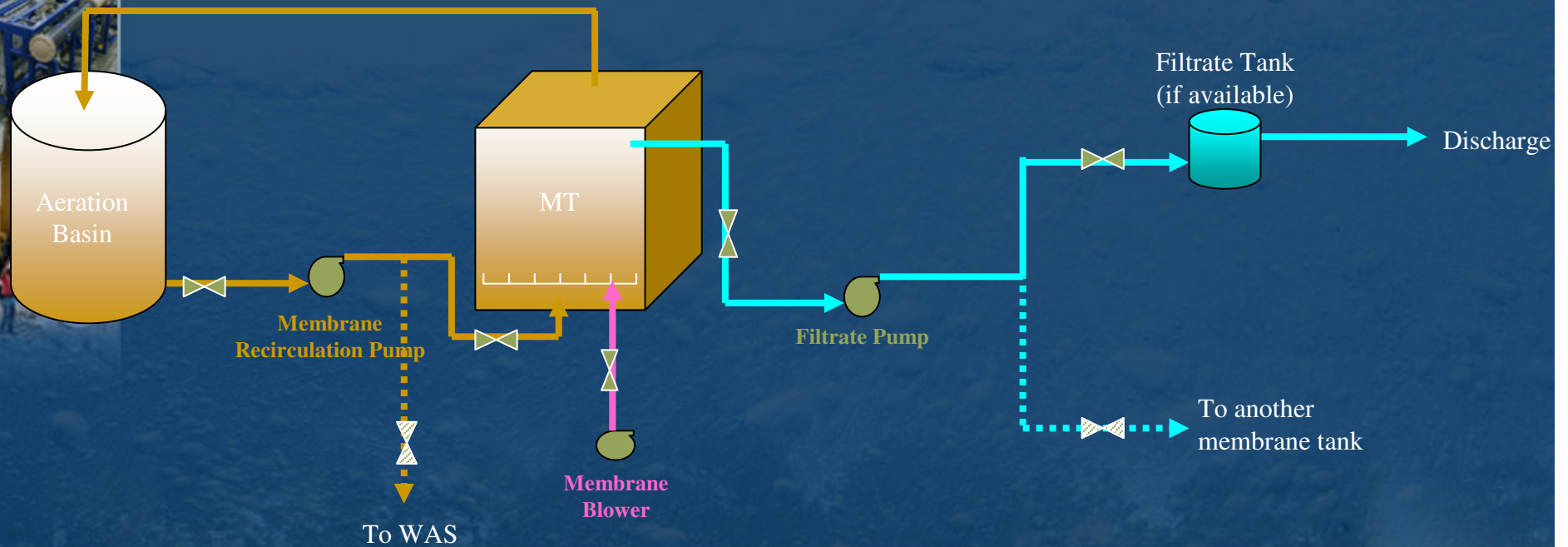
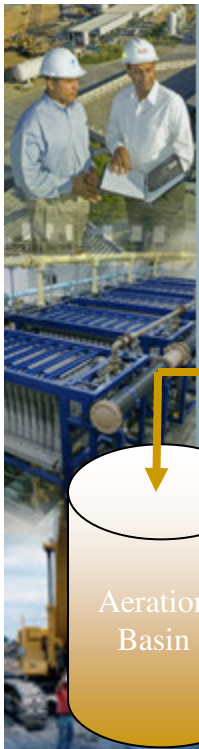




Main Equipment

- Membrane equipment:
 - Membrane Recirculation Pumps
 - Membrane Blowers
 - Filtrate Pumps
- Other equipment:
 - Fine Screen
 - Compressor



Filtration and Sludge Wasting



 Closed Valve
 Opened Valve

 Pump Off
 Pump On



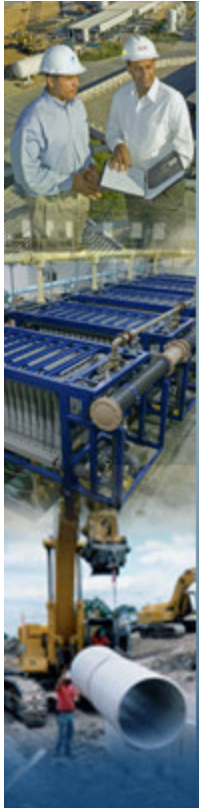


Fine Screen

Poor prescreen will cause fibers and debris to be trapped in fiber bundles restricting movement and impacting membrane performances and maintenance and cleaning frequency



Influent Screen Don'ts



Plugged With
Large Debris



Surface Area
Clogged Due
to Inadequate
Spray System



Unsafe
Working
Conditions





Tools Needed for Successful Implementation

- Compressor Selection Criteria:
 - Efficient removal of water, oil or other debris that could enter the compressed airlines
 - Carefully choosing where to install each piece of equipment (water traps, oil filters ...)

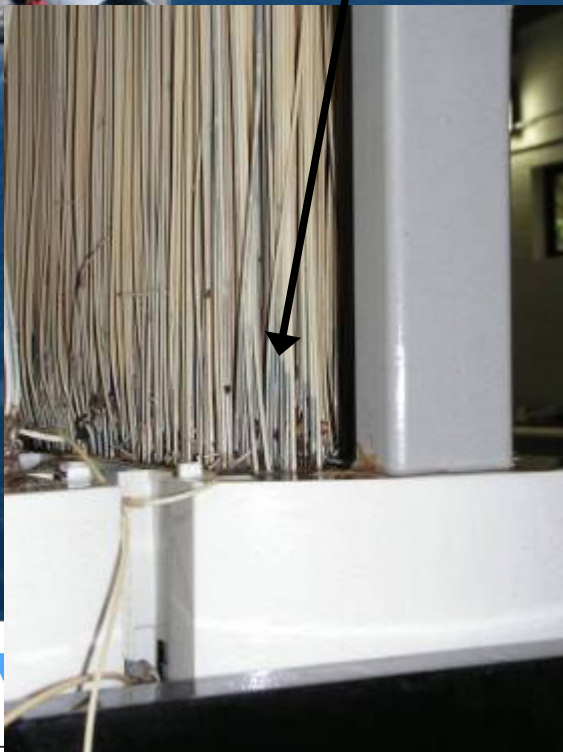


Membrane System Don't's

Sludge Trapped Inside
Fibers, Broken Fibers-
Integrity Issues



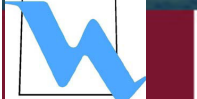
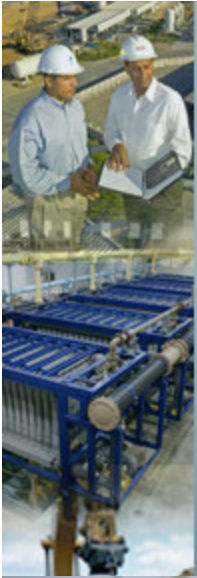
Debris (Rags, Gloves,
Plastic Tubing...) Stuck In
Aerator Slots



Membrane System Don't's

Debris Stuck On Top
Of Membranes
Fibers-Inadequate
Screening

Sludge Packing –
Reduced Flux Rate



Membrane System Don't's

Air Guides Broken,
Missing, and Pieces
Found Blocking Air
Slots



Membrane System Don't's

Trapped Scum/Foam

High MLSS > 15,000 mg/L





Other Don'ts

- Influent Channel
 - Poor Loading Distribution to Process Trains
 - Direct Overflow of Unscreened Influent - Bypass
- Membrane Cleaning Tank
 - Hazardous Task Moving Cassettes to Tank





Questions?

marie-laure.pellegrin@hdrinc.com

HDR

ONE COMPANY | *Many Solutions™*

